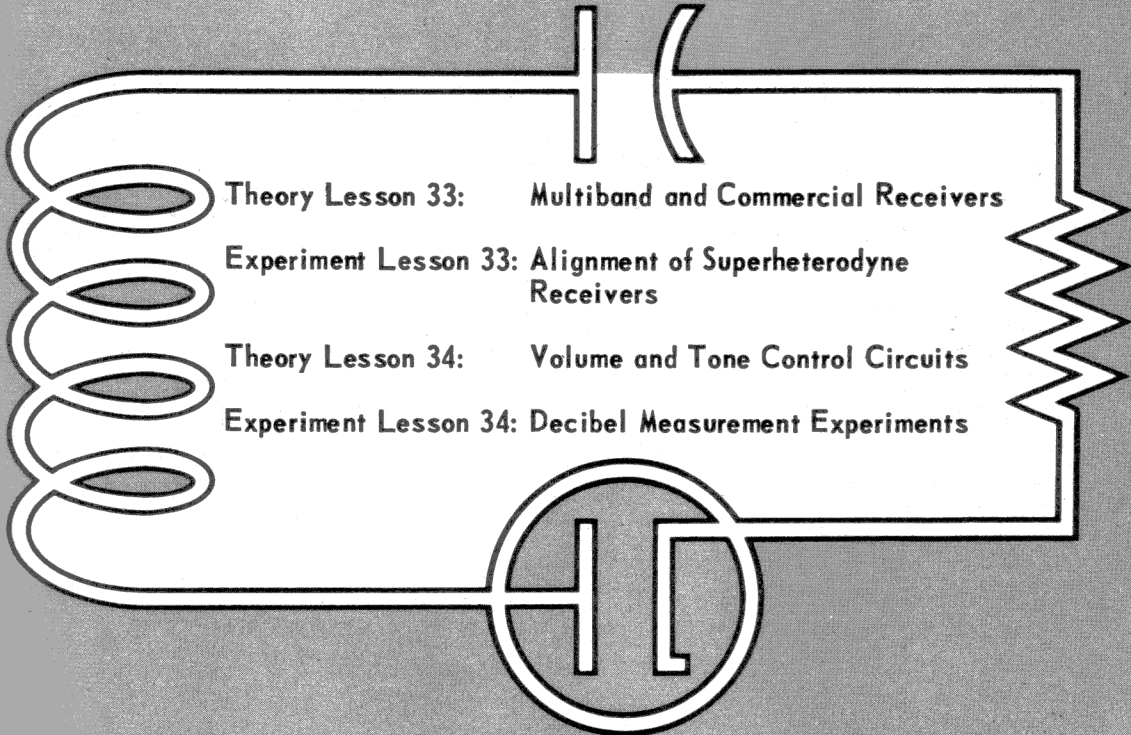


ELECTRONIC FUNDAMENTALS



Theory Lesson 33: Multiband and Commercial Receivers

Experiment Lesson 33: Alignment of Superheterodyne
Receivers

Theory Lesson 34: Volume and Tone Control Circuits

Experiment Lesson 34: Decibel Measurement Experiments



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York.

N. Y.

ELECTRONIC FUNDAMENTALS

THEORY LESSON 33

MULTIBAND AND COMMERCIAL RECEIVERS

33-1. Simple Broadcast — Short Wave Receivers

33-2. Console-Type A-C Operated Multiband Receivers

33-3. Communications Receivers

33-4. A Popular 3-Way Multiband Receiver



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Theory Lesson 33

INTRODUCTION

The exciting possibilities of short wave transmission and reception were not recognized by engineers and technicians when radio broadcasting to the public began. Wavelengths below 200 meters (1,500 kc) were regarded as intrinsically limited in their transmission range. They were not sought as desirable allocations by commercial broadcasters. They were assigned by the government to amateur operators, or *hams*, as these operators called themselves.

Within a few years, the amateurs demonstrated that the waves below 200 meters in length were capable of exceptional transmission ranges; that the shorter the waves were, the greater were the distances that could be consistently covered, until wavelengths as short as 20 meters (14 mc) were reached. American amateurs were able to establish two-way communication with other amateurs as far away as Australia. At wavelengths below 20 meters, the transmission range did not increase; at 10 meters it began to decrease rapidly.

Once the long-range advantages of short waves were demonstrated, commercial operators eagerly sought them for numerous services. Transoceanic telephone links, intercontinental news services, aircraft-to-ground and ground-to-aircraft communication, wire-photo, facsimile, and other services became far more efficient because of them. All over the world, new stations went on the air — run by private operators, amateurs, and governments. World-wide transmissions became commonplace. Complex beam-forming antennas made it possible for a transmitter to radiate most of its energy in a given direction, thereby greatly increasing the signal strength and reliability of reception at the intended receiving point.

All this varied activity aroused public interest in short-wave transmissions, and created a market for short-wave receivers.

The receiver usually used for the reception of short-wave programs is called a multiband receiver. The range usually covered by multiband receivers is from 540 kc to 31 mc, or, expressed in wavelengths, 555 to 9.7 meters. This range is generally divided into several short-wave bands and the broadcast band. There is no established rule for dividing the range into bands. The choice is based on preferences of individual manufacturers. Table A shows how two leading manufacturers made the division in the deluxe models.

TABLE A — BAND DIVISION

Manufacturer A	Manufacturer B
0.550 mc to 1.7 mc	0.540 mc to 1.32 mc
1.7 mc to 5 mc	1.32 mc to 3.2 mc
5 mc to 14 mc	3.2 mc to 5.7 mc
13 mc to 31 mc	5.7 mc to 10 mc
	10 mc to 18 mc
	18 mc to 31 mc

When the receiver is an economy a-c/d-c model, offering only the broadcast band and one short-wave band, the short-wave band chosen is usually 6 to 18 mc because this range covers numerous European, South American, African, Asian, and Australian transmissions.

You have already learned about how radio waves travel in two ways — along the

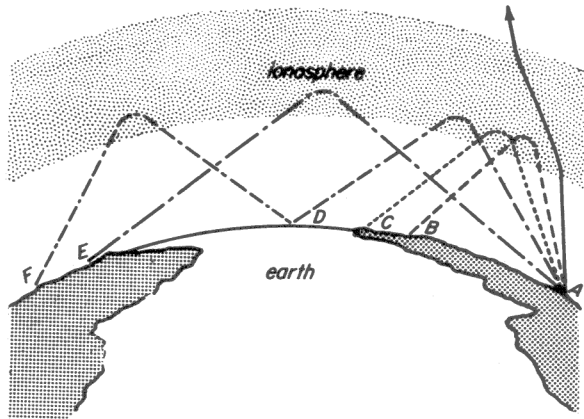


Fig. 33-1

ground, and up to the ionosphere, which reflects them back to the earth. A long wave reflected from the ionosphere does not, except under rare conditions, bounce back from the earth. However, a short wave, returning from the ionosphere to the earth may be reflected up again by the earth's surface, whether land or water. Thus, it may bounce back and forth between earth and ionosphere, making two, three, or more hops, following the curvature of the earth, and encircling it. Figure 33-1 shows some short-wave paths.

33-1. SIMPLE BROADCAST - SHORT WAVE RECEIVERS

The input circuit of a two-band superheterodyne receiver is shown in the schematic of Fig. 33-2. No changes are made in

the remainder of the set when the bandswitch is thrown from the broadcast-band position to the short-wave band position.

The moving contacts of the switch (S_1 , S_2 , and S_3) are ganged together, so that when S_1 is thrown to the contact point of the short-wave antenna transformer T_1 (a transformer is used in place of a single antenna coil so that the weak voltage of the short-wave signal can be stepped up), the other two moving contacts are thrown to the contacts of an appropriate short-wave oscillator tank coil, L_5 . Thus, when the r-f input circuit is tuned to a frequency in the short-wave band, the oscillator tank is tuned to a frequency 455 kc higher than the incoming r-f short-wave signal. The short-wave signal produces a 455-kc i.f. and sidebands in the i-f system. The i.f. is amplified and detected as usual. The recovered audio signal passes through the audio amplifier and becomes powerful enough to actuate the loudspeaker.

The short-wave oscillator tank coil and the short-wave r-f transformer have fewer turns than the inductors for the broadcast band. This gives them much lower inductance, so that they respond to higher frequencies when, together with the sections of the

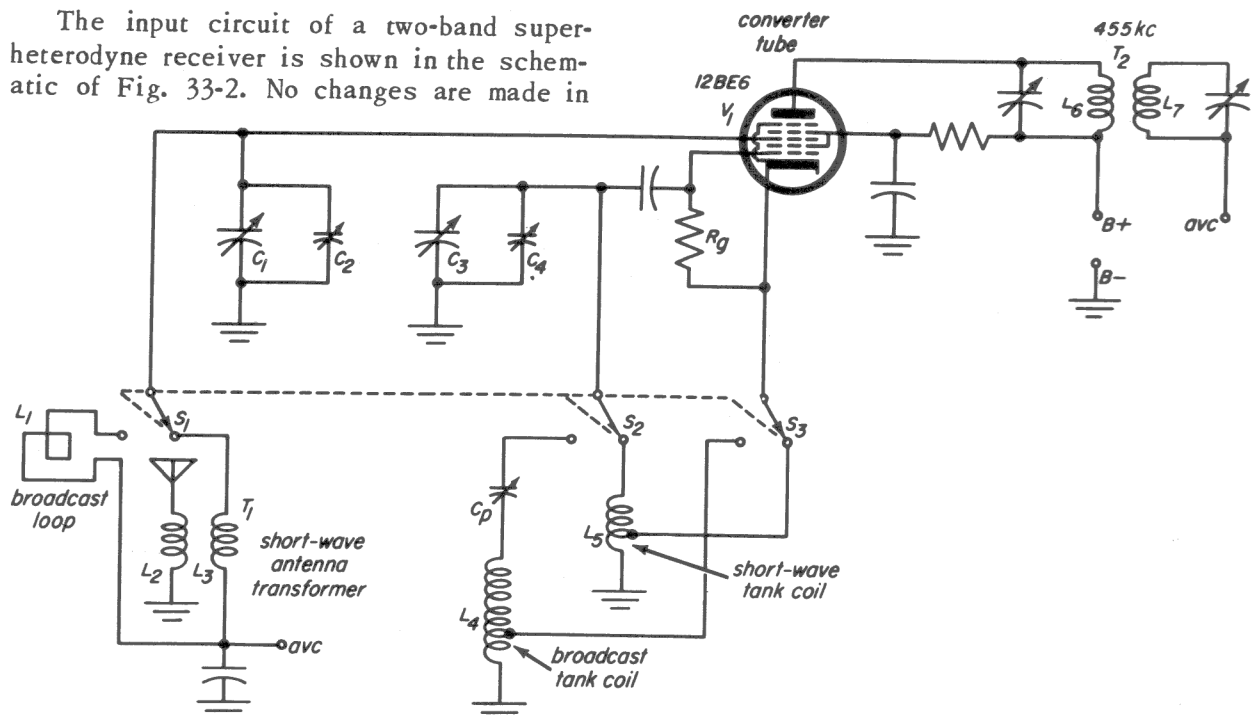


Fig. 33-2

variable capacitor, they form resonant circuits.

When the bandswitch is thrown to the broadcast-band position, an ordinary loop antenna is used to pick up the r-f signal. An r-f antenna transformer could be used instead, but then a fourth moving contact would be needed on the bandswitch to switch the external antenna, A, from the primary of the short-wave antenna transformer to the primary of the broadcast antenna transformer. As it is, the external antenna does not need to be switched, since it is used only during short-wave reception. Local stations provide such high signal strength that a loop's pick up is usually adequate.

Note the padder capacitor, C_p , in series with L_4 , and the variable capacitor, C_3 , shunted by trimmer C_4 . The padder is needed only on the broadcast band to correct the range of capacitance variation when the oscillator tank circuit is tuned. (If necessary, review the discussion of padder function in Theory Lesson 29).

In this circuit, the padder may not be located between the lower end of L_4 and B- (ground). If it were, the d-c component of the plate current of V_1 would be unable to flow between B- and cathode. With the d-c circuit broken, no plate current at all would flow through the tube. The tube would not function.

With modern high-gain tubes and an ordinary outdoor antenna, a receiver such as this is sensitive enough to receive short-wave signals from transmitters located on the other side of the globe. But such a receiver is susceptible to image interference on the short-wave bands.

Image Rejection at High Frequencies. Since the image is higher than the desired signal by an amount equal to twice the i.f., the separation in the receiver just discussed would be 910 kilocycles. This is a reasonable margin in the broadcast band. For a desired signal at 1,000 kc, the image frequency would be at 1910 kc. The formula for determining the image signal's off-resonance percentage is:

$$\text{Image off-resonance \%} = \frac{\text{image separation}}{\text{desired signal frequency}} \times 100$$

In this case:

$$\text{Image off-resonance \%} = \frac{910 \text{ kc}}{1000 \text{ kc}} \times 100 = 91\%$$

An image signal that is 91 percent off resonance will produce negligible interference unless it is exceedingly strong and the desired signal is weak. With a 455-kc i.f., images are not a serious problem in the broadcast band.

But in the short-wave bands, images are a serious problem. Consider the same receiver tuned to a short-wave signal at 10 mc when there is a strong signal at 10.91 mc on the air. As before, the signals are separated by 910 kc, but now the percentage is very different:

$$\begin{aligned} \text{Image off-resonance \%} &= \frac{910 \text{ kc}}{10,000 \text{ kc}} \times 100 \\ &= 9.1\% \end{aligned}$$

The single tuned circuit at the receiver's input may not be able to select the desired signal and severely attenuate the undesired signal when the latter is off resonance by only 9.1 percent. The image signal may be able to reach the converter grid and produce an interfering i.f.

As frequencies rise, the image problem becomes worse. At 30 mc, the image would be off resonance by only 3.3 percent. Because of this relationship, designers of receivers intended primarily for short-wave reception include two or more stages of TRF amplification to provide selectivity ahead of the converter. Another technique is to use a very high i.f., such as 2 mc, to increase the separation between image frequency and

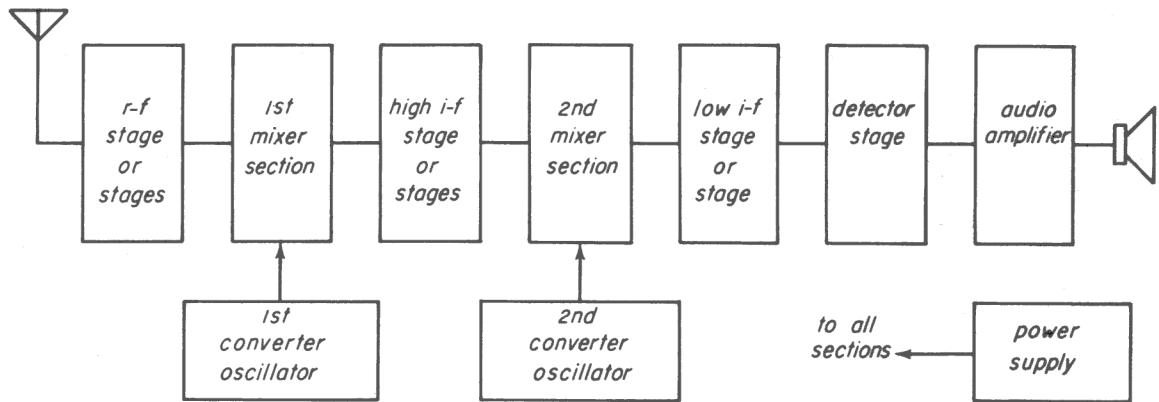


Fig. 33-3

desired frequency. Occasionally, designers include both of these precautions.

Double-Superheterodyne Receivers. Theory Lesson 29 explained why a high i.f., which is important to the prevention of image interference, is undesirable from the standpoint of adjacent-channel selectivity. Since good adjacent-channel selectivity is necessary in the crowded short-wave bands, it must not be sacrificed in order to combat image interference. An effective way to retain adjacent channel selectivity, and still combat image interference, is to use both a high i.f. and a low i.f. This seemingly contradictory requirement is achieved by a *double* superheterodyne receiver. Fig. 33-3 is a block diagram that shows the principle of the receiver.

The section labeled r-f stage selects the desired signal, provides a degree of selectivity and amplification, and then applies the signal to the first mixer section. At the first mixer section, the incoming signal and the local-oscillator signal from the first conversion oscillator heterodyne, developing a high i.f. of about 2 mc. Note that the r-f section and choice of a high i.f. are effective in reducing image response. The desired signal is then amplified by the high i-f section, and is applied to the 2nd mixer section, along with another local-oscillator signal from the 2nd conversion oscillator. The second mixer stage converts (by heterodyning) the high i.f. to a lower i.f. of about 100 kc. The low i.f. is then amplified in a fixed-tuned stage or stages and applied to the diode detector, where the audio information is recovered, after which it is amplified and reproduced.

In the low i-f section of the receiver, very good adjacent channel selectivity is established. The power supply provides the necessary operating potentials for all the sections.

33-2. CONSOLE -TYPE A-C OPERATED MULTIBAND RECEIVERS

These large, expensive, and usually elaborate receivers do not differ in principle from the small a-c/d-c receivers, but they do include many refinements to improve their performance. Representative refinements are the following:

- a. One or more TRF stages to improve image rejection and signal-to-noise ratio.
- b. Five or six bands.
- c. Large slide-rule type dial, to provide good readability and allow numerous frequencies to be marked without crowding.
- d. High tuning ratio, often combined with flywheel tuning so that both vernier action and rapid sweeping from one end of the band to the other are possible.
- e. Band indicators— usually dial lamps, turned on by the bandswitch— to show in what band the receiver is at the moment operative by illuminating the appropriate scale.
- f. Variable bandpass i-f transformers, to provide narrow bandpass when interference is encountered, and broad bandpass when a wide-range audio program is being received.

g. Good quality audio system with push-pull output stage, and large loudspeaker, to enhance the enjoyment of musical programs.

h. Multipoint, multideck, self-cleaning wafer switches to provide reliable contacts when switching from band to band.

i. Record player; occasionally an FM tuner.

The high-tuning ratio is important. A receiver that includes the higher short wave frequencies around 30 mc is very difficult to tune if there is no mechanical step-down ratio between the tuning knob and the variable capacitor. At thirty megacycles, rotating the capacitor plates one-tenth of a degree may tune the station out completely because, at high frequencies, a small change in capacitance makes a large change in resonant frequency. Adjustment of the capacitor is almost impossible unless the mechanical system that transfers knob rotation into capacitor rotation introduces a large mechanical advantage, so that the tuning knob has to be turned a large number of degrees in order to turn the capacitor shaft one degree. A ratio of twenty-to-one is not too much on the short wave band. With such a ratio, rotating the tuning knob one degree turns the capacitor shaft one-twentieth of a degree. With this advantage, tuning is not unduly critical. But a high tuning ratio means that to tune from one end of the dial to the other, the tuning knob must be rotated many times. This tedious task is eliminated by a system, called *flywheel tuning* (Fig. 33-4), which offers both high ratio and rapid sweeping over the dial. The high-ratio tuning is provided by the small diameter of the tuning shaft compared to the large diameter of the drive pulley on the variable capacitor shaft. Rapid sweep is provided by the heavy flywheel on the tuning shaft. The function of the flywheel is simple—to keep the shaft turning after one gives it a spin. If the tuning knob is given a strong enough initial spin, the momentum of the flywheel will keep the shaft turning rapidly, sweeping the tuning indicator across the dial in a few seconds.

Thus, it is possible to sweep rapidly across the dial to the vicinity of the station

you want and then use the high tuning ratio to tune exactly to the station you want.

33-3. COMMUNICATIONS RECEIVERS

The receivers we have discussed so far are classified as home-type receivers. They are intended for casual use to receive local AM broadcasts and broadcasts from foreign lands, marine and police communications, and other radio services. Where reliability of communication is of utmost importance as it is to the communications companies, the military, airlines, taxi and other fleet services, or the serious-minded short-wave listener or amateur radio operator, the home-type receivers are lacking, and the communications-type receivers are used.

Communications receivers are capable of receiving AM, CW, and SSB (single sideband) signals. As you know, AM signals consist of a carrier and a pair of sideband signals for each single a-f signal transmitted. CW signals are simply the r-f carrier keyed on or off according to a code — usually the International Morse Code. On the usual home-type receiver, AM signals can be heard intelligibly, and CW and SSB signals can not. However, CW and SSB signals can be properly received on the communications receiver because of certain provisions that are incorporated into the design of the receiver. Basically, all communications receivers are of the superheterodyne type. Ad-

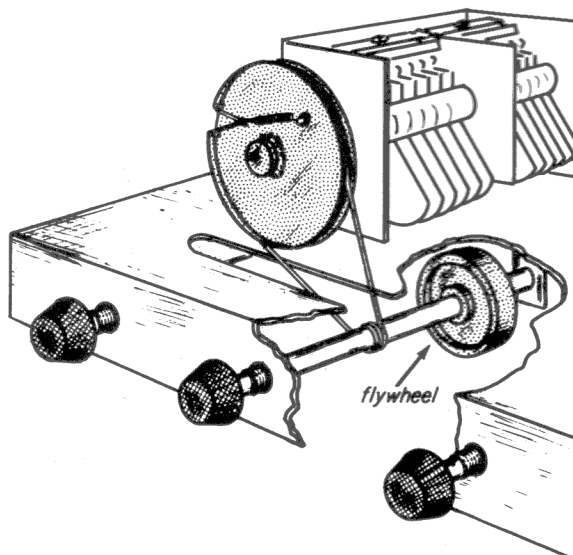
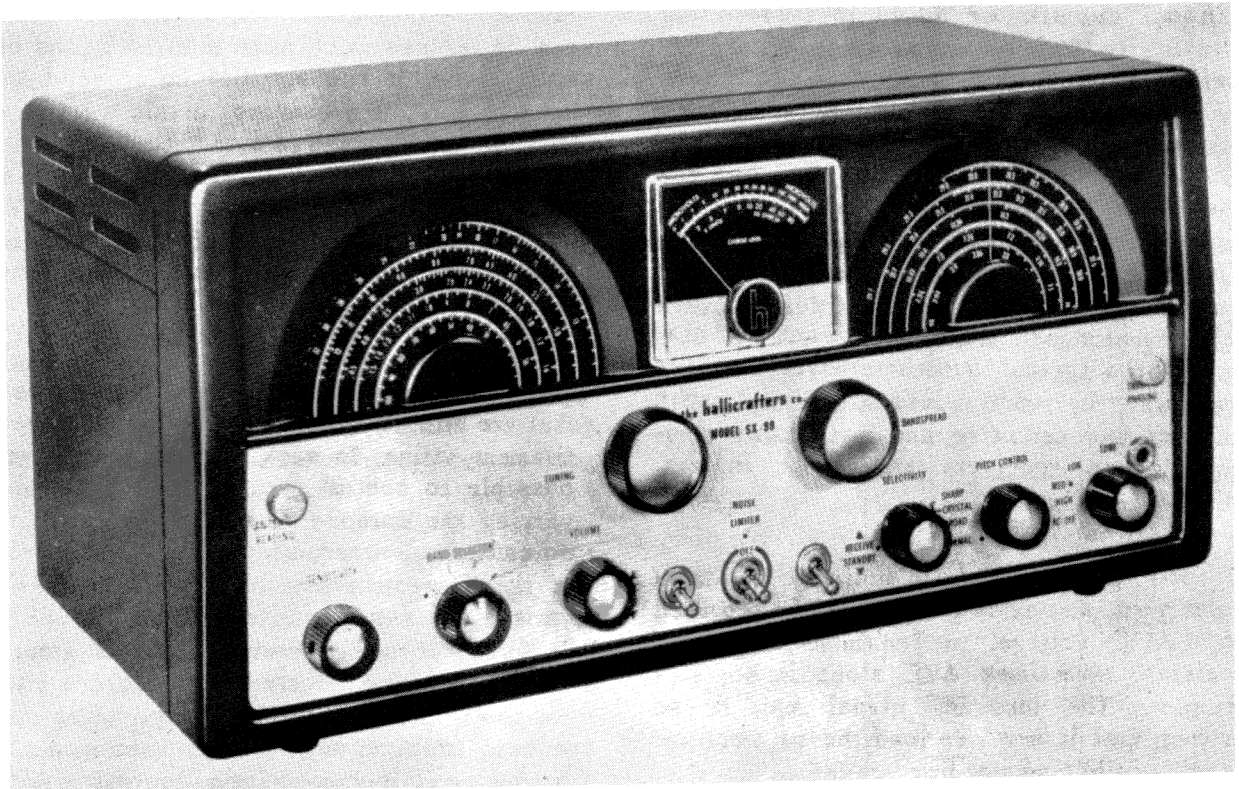


Fig. 33-4



(a) Hallicrafters Model SX-99



(b) Hammarlund HQ-140-XA

ditional circuits are added to improve the sensitivity and image rejection of the receiver (by the addition of one or two stages of tuned r-f amplification). Circuits, such as the sensitivity control, crystal filter, noise limiter, and others are incorporated into the communications receiver. These will be studied in detail in this section of the lesson. Only that part or section of the receiver that incorporates the specific individual circuits will be reproduced. A complete schematic diagram of a typical superheterodyne receiver appears in this lesson. Photographs of two representative and well-known communications receivers are shown in Fig. 33-5.

R-F Gain Control. In ordinary broadcast receivers, automatic gain control is provided by AVC voltage. In communications receivers, sometimes AVC alone is not sufficient. The incoming signal may be so strong that it will overload the r-f amplifier and possibly succeeding stages in spite of AVC. At other times, for reasons that will be explained later in this lesson, AVC bias must be eliminated. Additional gain control is needed either to supplement or take the place of AVC.

This gain control is provided by using a variable cathode resistor in the r-f circuit, as shown in Fig. 33-6a. This resistor is a front-panel control—one of the additional controls you must be familiar with in order to operate a communications receiver. Sometimes it is labeled R-F GAIN and sometimes SENSITIVITY.

Let's consider how the SENSITIVITY control is used to supplement AVC. As shown in Fig. 33-6a, the wiper of the SENSITIVITY control is grounded. The negative end of the AVC circuit is connected to the control grid; the positive end is grounded. Note that the upper end of R_1 , the cathode-bias resistor, is positive; the lower or negative end is grounded. Therefore, the AVC voltage and the voltage across the cathode bias resistor are series aiding. When the resistance of the SENSITIVITY control is increased, the voltage drop across it increases and adds to the AVC voltage. Therefore the total negative voltage applied between control grid and

cathode is increased. The gain of the tube can be reduced much more than by means of AVC alone; it can actually be reduced almost to zero, if necessary. In this way, signals powerful enough to overcome AVC alone are attenuated and kept from causing distortion in succeeding stages. The SENSITIVITY control, R_1 , is bypassed by C_1 to prevent signal voltages from developing across R_1 .

Some communications receivers use tubes that are directly heated by a battery operated filament string. In such receivers, it is not possible to control gain in an r-f stage by varying the cathode bias, because there is no cathode. Instead, as shown in Fig. 33-6b of the figure, the bias of the screen grid is varied by means of connecting the SENSITIVITY control between B+ and ground with the wiper connected to the screen grid. As the wiper is moved toward ground, the voltage drop across R_1 increases and the screen grid becomes more negative with respect to B+. Therefore the gain is re-

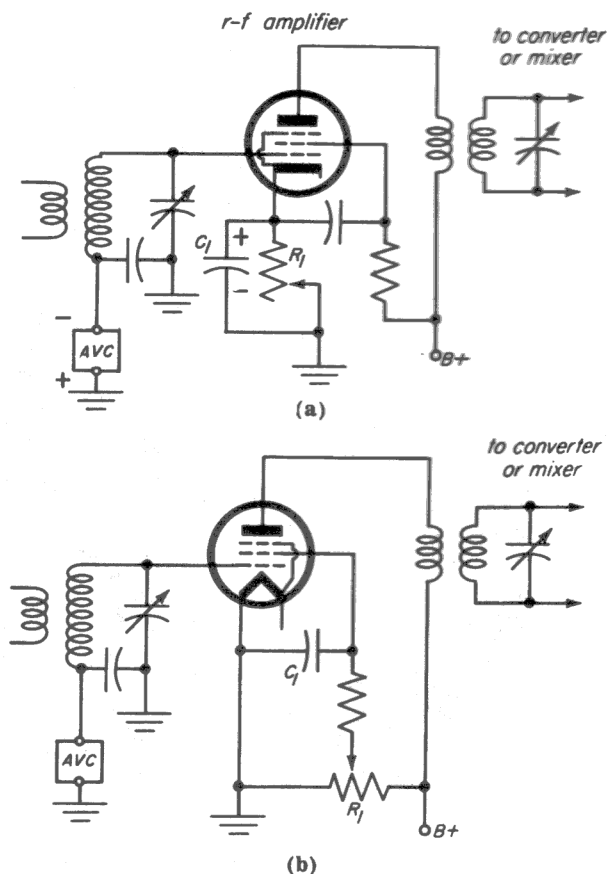


Fig. 33-6

duced. C_1 bypasses signal voltages to ground.

Another type of communication called *radio-telegraphy* makes efficient use of the carrier. This system, which makes use of continuous wave (CW) transmission is very simple to understand. The transmission consists simply of turning the unmodulated carrier on and off. The carrier can be turned on, left on for a short time, and turned off, thus producing a short burst of energy. This short burst is called a dot. A burst of energy three times as long, which results when the carrier is transmitted for three times as long as a dot, is called a dash.

When the carrier is switched on, power goes from zero to maximum very quickly and remains at maximum. When it is shut off power falls from maximum to zero very quickly. As you know from your study of broadcast receivers, an unmodulated carrier produces no response at the loudspeaker. The fact that there is a change in power when the carrier is turned on and another change in power when the carrier is turned off may produce audible clicks in a broadcast receiver, because at these points the amplitude is changing. However, whenever the unmodulated carrier is not rising or falling, but remains steady at maximum, there is no sound at the loudspeaker of the broadcast receiver.

Beat-Frequency Oscillator. In the communications receiver, the CW signals at r.f. are converted to the i.f. To make the CW signals at i.f. audible, a beat-frequency oscillator (BFO) is used (Fig. 33-7). A BFO is a simple oscillator that oscillates near the i.f. and the output of which is injected into the i-f amplifier. For example, let us assume that the i.f. of the receiver is 455 kc and the BFO is oscillating at 456 kc. At the second detector, two signals will heterodyne and produce a 1-kc audio note at the second detector output. This note will be heard every time the carrier is on. This shunt-fed Hartley oscillator has a variable tuning coil that permits tuning the oscillator to a frequency that is different from the i.f. by an amount within the audio range.

The output of the detector is an audio signal that is amplified by the audio ampli-

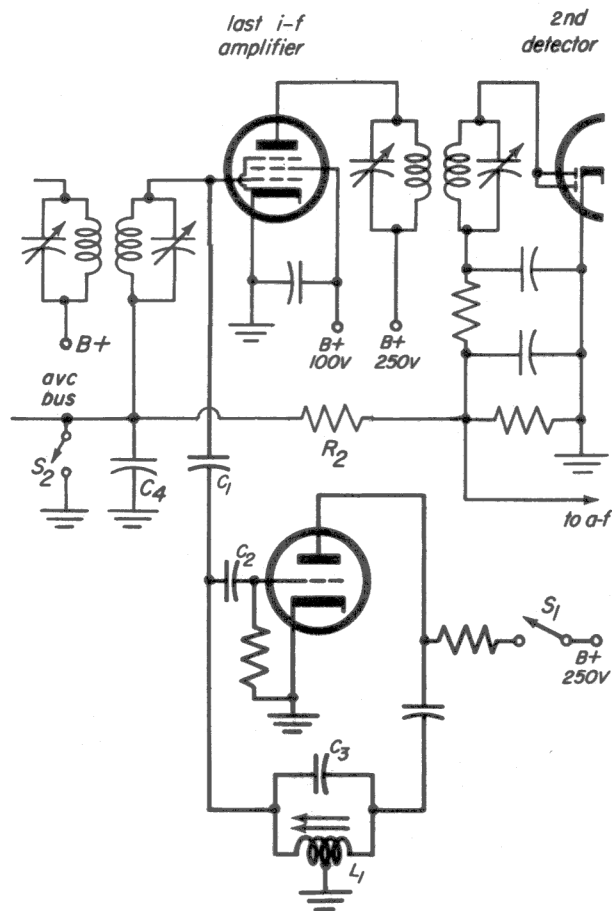


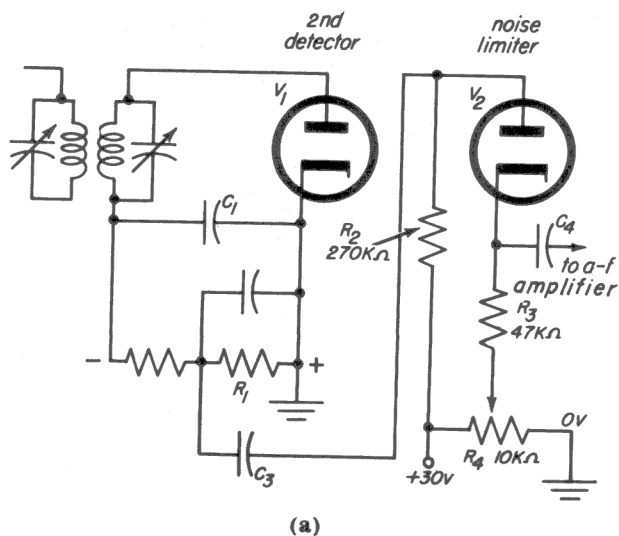
Fig. 33-7

fier and is heard as a series of shrill notes corresponding in length to the dots and dashes sent out by the transmitter. In some receivers, the audio tone may be made more or less shrill by varying the tuning coil of the BFO. In other receivers, the BFO uses a variable tuning capacitor instead of a variable tuning coil, and the pitch of the tone can be varied by varying the capacitor. The more the resonant frequency of the tuning circuit differs from the i.f., the higher is the pitch heard by the listener. The less the resonant frequency differs from the i.f., the lower the pitch. When the oscillator frequency and i.f. are the same, no beat is produced. This oscillator is said to be zero beat.

In the reception of ordinary AM transmissions, the AVC voltage developed in the detector stage varies with the strength of the incoming signal. In the reception of CW signals, AVC voltage does *not* vary with the strength of the incoming signal. This is due to the BFO signal, needed when receiving

CW transmissions. The BFO signal is the equivalent of a strong, unvarying i-f carrier. When the incoming CW signal fades, the BFO signal, generated in the receiver, does not fade with it, but remains constant. The AVC voltage developed is from the unvarying, rectified BFO carrier. As a result, AVC voltage is constant and cannot adjust the gain to fit the needs of the incoming signal. Not only is AVC constant under these conditions, but it is also large, so that it holds the receiver gain at a low level. It is actually a handicap to reception of signals, unless they are very strong.

Communications receivers are provided with a switch that enables the operator to disable AVC action. Figure 33-7 shows



(a)

where the switch, S_2 , is usually connected. It simply shorts the AVC voltage. The grids of the r-f and i-f amplifier tubes are held at ground potential, so that they can provide maximum r-f and i-f gain. The short is across C_4 , but shorting the AVC filter capacitor does not short the detector's audio output; the high value filter resistor R_2 isolates the short from the detector load.

With AVC disabled, large variations in signal strength will cause large variations in audio volume. A skilled operator can hold these variations within comfortable limits by turning the manually operated r-f gain control.

The AVC on-off switch may be ganged with the BFO on-off switch in such a way that when BFO is switched on, AVC is automatically switched off.

The principle advantage of the CW plus BFO method of communication is that it allows a transmitter with a given amount of power to put more intelligibility into the signal. The same transmitter, used for voice

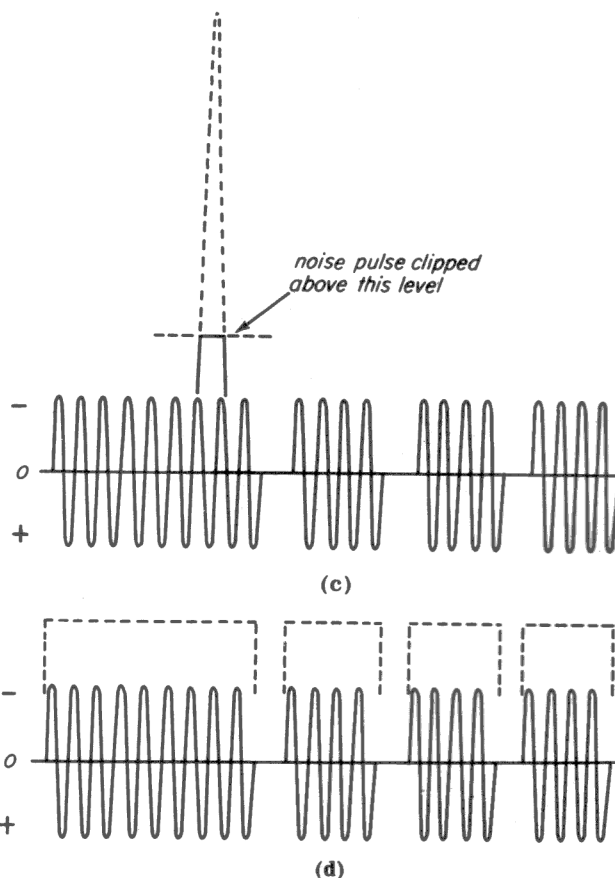


Fig. 33-8

transmission, would have to allocate about one-third of the total power for sidebands, leaving the rest for carrier power. Only the modulating sidebands would contain the information, and only certain speech sounds (vowels) would modulate deeply. The hissing sounds would modulate the carrier very little. A speech-modulated carrier sent for thousands of miles arrives at its destination with less than a billionth of its original power. The faint hissing sounds and sounds of many consonants are lost against a background of intense hissing and crackling due to noise. In contrast, the shrill CW notes are well heard against such a background. They have a distinctive pitch because they represent, in effect, 100-percent modulation of the carrier burst.

Noise Limiter. Although some noise may be excluded by extreme selectivity, the part of the noise background that does get through may be amplified to a very high level.

A type of noise called *pulse* or *shot noise*, because it is characterized by high amplitude-short duration peaks, may be severely attenuated by a biased diode in a circuit such as that of Fig. 33-8.

In the second detector circuit shown, the positive end of the detector load resistor is grounded. Therefore the output of the detector consists of negative-going voltages. The noise pulse shown at *b* is an abrupt, high-amplitude, negative-going pulse, in the output of the detector.

The plate of V_2 is connected via C_3 to the negative side of the load resistor of V_1 . A low B+ of 30 volts is applied to the plate of V_2 . Therefore, the plate of V_2 is positive in inverse proportion to the strength of the negative going signal across the load of V_1 , which opposes the B+ voltage on the plate of V_2 . When any incoming signal or noise across R_1 is great enough to completely overcome the B+ on the plate of V_2 , the plate of V_2 is driven negative and V_2 no longer conducts. Therefore there is no output voltage across R_3 , the load resistor of V_2 , and no input to the audio amplifier.

Thus, when the negative-going signal noise is too high, its peaks are clipped. A

high noise pulse, as shown in *b* of the figure, is clipped by the noise limiter, as shown at *c*. The level at which clipping occurs can be adjusted by varying the bias resistor, R_4 . If the incoming signal is too high, due to an atmospheric change, it too will be clipped, as shown in *d*. This does not matter at all. The remaining portion of the dots and dashes will still be fairly distinct and readable. CW signals, unlike speech voltage variations, do not depend upon the relative amplitude of one dot or dash to the next.

For speech to be clear, audio signals must not vary much from their correct *relative* intensities. If a limiter with manually set bias clips certain tones and not others as the speech level rises and falls, due to fading or other cause, the relative intensities of tones may be altered enough to garble the speech seriously. This problem can be considerably resolved by use of an automatic noise limiter (ANL).

Automatic Noise Limiter. The circuit shown in Fig. 33-9 features a diode pulse limiter, V_2 , whose bias varies with the incoming i-f carrier. The load of the diode detector, V_1 , consists of two equal resistors R_3 and R_4 in series, forming a voltage divider bypassed for i.f. by C_3 . Suppose an incoming carrier makes point A -3 volts with respect to ground. Then, due to the voltage divider, point C, the plate

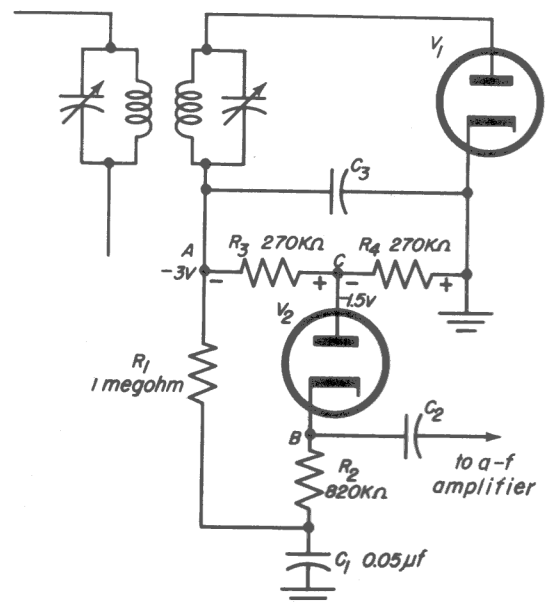


Fig. 33-9

of V_2 , will be only half as negative, or -1.5 volts with respect to ground. That is, point C will be +1.5 volts with respect to point A . Point B , the cathode of V_2 , is connected by R_1 and R_2 to point A . Point B will therefore be negative with respect to Point C , so V_2 will conduct. Audio voltage variations in the detector load will vary the electron stream of V_2 , as long as V_2 is conductive. An audio signal will be developed across R_2 , just as it was developed across R_3 in the preceding noise limiter. From point B , the signal can reach the audio amplifier through C_2 .

If the carrier signal gradually increases, so that point A becomes -6 volts, point C becomes -3 volts. But point C , the plate of V_2 , does not thereby become negative with respect to point B , the cathode, because the cathode also becomes more negative as point A becomes more negative. The voltage at point B can follow the gradual changes at point A . But if a noise pulse abruptly changes the voltage at A from -3 to -20, let us say, point B *can not* follow the abrupt change. Capacitor C_1 prevents abrupt changes at A from applying abrupt voltage changes to B . Before a voltage change at A can affect the bias at B the change at A must have time to alter the charge on C_1 . But R_1 and C_1 constitute a filter with a time constant of 0.05 second. This is long compared to a noise pulse. The pulse would be over before any appreciable change occurred at B .

But, the voltage on the plate of V_2 *can* change abruptly with noise pulses. When A becomes -20 volts, C becomes -10 volts. The plate of V_2 becomes more negative than the slow-changing cathode. Conduction ceases. The noise pulse does not reach the audio amplifier.

Because the plate of V_2 is connected to the mid-point of the detector load, it cannot be driven beyond the cut-off level by large audio signal variations. At 100-percent modulation, audio peaks rise to just twice the unmodulated level of the carrier—that is to twice the carrier's average level. The average voltage at point A and, therefore, the average voltage at point B are determined by the carrier's average level during an in-

terval of several audio cycles. If a strong audio variation at C makes C suddenly as negative as possible at 100-percent modulation, the voltage at C will momentarily be *equal* to the bias voltage at B but will not be more negative than the voltage at B .

This is due to the midpoint connection of C and the voltage divider action of the detector load. When C momentarily rises to twice its average potential, it just equals the average potential of A .

In the above explanation of the principle of the automatic noise limiter, it has been implied, for the simplicity's sake, that points A and B are at the same potential. Actually B is slightly less negative than A , for the value of R_3 given. This is due to the voltage drop across R_1 and R_2 , caused by the small current flowing across the diode through the two resistors. Therefore the average voltage at B will not be twice as negative as the average voltage at C . Slight limiting of audiopicks will occur at 100-percent modulation. This may be corrected, however, by increasing the resistance of R_3 , which increases the difference of potential between C and A . A value of R_3 can be found for which the average voltage at B *will equal* twice the average at C . Then no audio limiting will occur.

The loss in audio output due to changing the ratio of voltage division in the detector load can be compensated by advancing the volume control.

The main damage done by strong noise pulses is that they greatly desensitize the ear for a fraction of a second during and following the pulse. Audio information immediately following the pulse is not heard. When noise pulses are loud and frequent, and unclipped, enough audio information may be lost to render a message unintelligible.

Crystal Filter. The i-f system of a communications receiver can be made very selective by including in one of its stages a crystal (piezoelectric quartz) filter, resonant to the i.f. Figure 33-10a shows the circuit of such a filter.

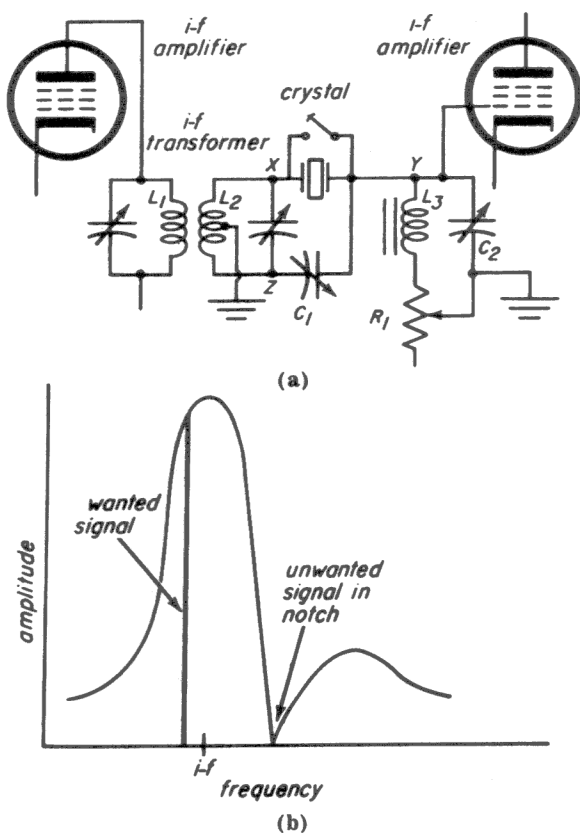


Fig. 33-10

The type of crystal used in this circuit has a double nature that depends upon the frequency applied to it. For signals at, or very close to, the frequency for which it was cut, it acts as a series-resonant circuit; for frequencies slightly off resonance it acts as a parallel-resonant circuit. Its Q is extremely high—far higher than that of any simple LC circuit. Therefore, its impedance at series resonance is very low, and at parallel resonance very high. Due to the way in which the molecules of the crystal vibrate, its resonance curve is not symmetrical but has a sharp notch (corresponding to extremely high parallel-resonant impedance) at one side, as shown in the figure at *b*.

The crystal is used in the i-f system as a series-resonant coupling between L_2 and L_3 . Its low impedance at the i.f. allows signals at, or extremely close to, the i.f. to pass without attenuation from point X to point Y . For frequencies appreciably off resonance it presents a high impedance path between X and Y , thereby attenuating them. For signals off resonance by as little as a few hundred cycles, it can offer severe attenuation.

C_1 , the small variable capacitor shown in the figure, is required to neutralize the effect of the two metal plates that hold the crystal. These plates have an inherent capacitance of their own. With C_1 omitted, the capacitance between the holder plates would allow signals rejected by the crystal, to pass, by ordinary capacitive coupling, from X to Y . L_2 is grounded at its center-tap. If a positive-going signal appears at X , a negative-going signal of equal amplitude appears at Z . With C_1 in the circuit, and set to a capacitance just equal to that between the holder plates, any signal able to reach Y via the holder plate capacitance will be cancelled by signal of equal and opposite polarity reaching Y via C_1 .

Thus, the only signals able to pass from X to Y are those accepted by the crystal alone. C_1 is called a phasing control. R_1 , between the lower end of L_3 and ground, is a variable resistor of from 0 to 5,000 ohms. It is in the resonant circuit L_3C_2 . It controls the bandwidth of this resonant circuit and of the crystal by varying the loading effect of the resonant circuit on the crystal. When R_1 is set to zero resistance, the over-all selectivity of the stage approaches that due to the crystal only. When R_1 is set to a high resistance, the bandwidth is broadened approaching that of the resonant circuit. With this arrangement, bandwidth may be varied from about 100 cps to several kilocycles.

In Fig. 33-10*b*, notice the notch at whose corresponding frequency the crystal's response is practically zero. If an undesired i.f. can be made to fall in this notch, it will be attenuated severely. It will have a high (parallel-resonant) impedance blocking its path from X to Y . We know that the frequency of the output of the mixer can be varied slightly above or below 455 kc (or any other i.f.) by varying the tuning of the oscillator tank. If an interfering signal appears in the i-f system along with the desired signal, it is often possible, by slightly detuning the receiver, to make the undesired i.f. shift frequency enough to place itself in the notch. It will then be almost completely eliminated. The detuning may reduce the gain for the desired signal somewhat, but this is not important if the interference is reduced by a far greater amount.

Bandspread Tuning. On the broadcast band, rotation of the tuning capacitor from fully open to fully closed changes the resonant frequency of the r-f circuit, and of the oscillator tank circuit; by 1,120 kc (1,650-530 and 2,105-985). In the 6- to 18-mc short-wave band, rotating the capacitor from fully open to fully closed changes the resonant frequency of the two circuits by 12,000 kc (18,000-6,000 and 18,455-6,455). That is, the same amount of capacitor-shaft rotation produces over ten times as much frequency change in the short-wave band. Therefore, rotation of the capacitor even a tiny amount can tune a short-wave station out completely.

One way of overcoming this critical tuning has been mentioned—high ratio drives between tuning knob and variable capacitor. Another method, widely used in communications receivers, is the use of an additional variable capacitor. This added variable capacitor (Fig. 33-11a), which has only one rotor plate, is called a bandspread capacitor because, on its dial, the stations are spread out far more than on the main dial. However, it spreads only a small portion of any one short-wave band. Figure 33-11b shows one main section and one bandspread section of the ganged capacitor. It is usually built into the same frame with the main variable capacitor. A separate shaft is provided for turning the bandspread rotors. A bandwidth capacitor has about one-tenth the capacitance range of the main tuning capacitor with which it is used. Therefore, in order to produce a given frequency change in a resonant circuit, a bandspread capacitor must be turned ten times as many degrees as a main rotor section. It is only one-tenth as critical to adjust.

In order to tune to a particular station, start with the bandspread knob set so that the bandspread rotor plates are almost out of mesh. Turn the main tuning knob until the dial scale and indicator tell that you are on station. Then turn the bandspread knob slowly clockwise or counterclockwise until the desired signal is heard. Carefully adjust the bandspread knob for loudest response. This procedure uses the main tuning dial merely to get close to the desired station, which is easy to do; then it avoids the

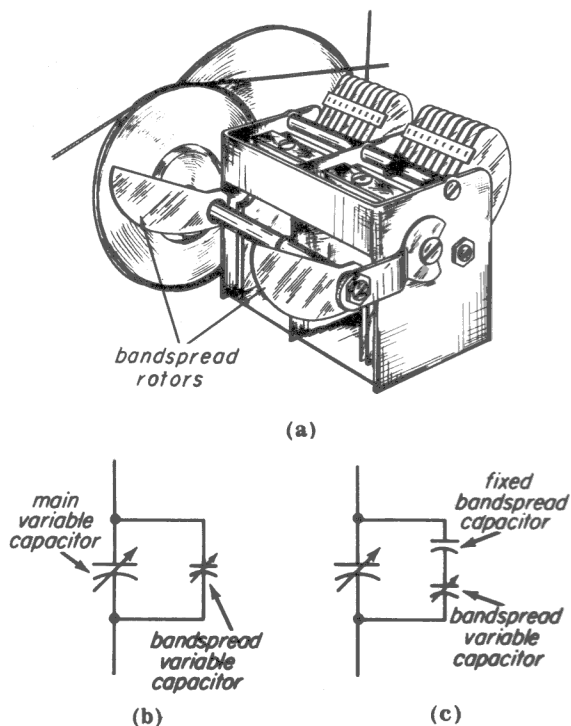


Fig. 33-11

critical exact tuning of the main capacitor rotors by using the bandspread rotors to make further capacitance changes until exactly the right amount of total capacitance is in the resonant circuits.

In order to sweep over a small part of any short-wave band so as to discover what signals are on the air in that particular small range, start with the main tuning dial set to the highest frequency in the narrow band you're interested in and the bandspread fully open. Slowly rotate the bandspread knob toward the fully closed position. As the bandspread rotor slowly meshes, it will gradually lower the resonant frequency of the r-f and oscillator circuits until all signals in the range have been swept over. This very gradual change of resonant frequency ensures that no signal will be passed over so quickly that it will be missed or mistaken for a noise pulse. Such gradual change could not easily be made by tuning the main knob. When the narrow range has been fully swept, you can set the main tuning indicator to the highest frequency in the next narrow range and repeat the procedure we have just discussed. By taking one narrow range at a time, you can fully monitor a complete short-wave band with the bandspread capacitor.

The bandsread can be increased—that is, it is possible to tune slowly over an even narrower range by means of placing a padder in series with the bandsread capacitor, as shown in Fig. 33-11c. This series combination has less capacitance than the bandsread capacitor alone. Therefore, full rotation of the bandsread rotor cause less change in the total capacitance in the circuit. More degrees of rotation are required to produce a given frequency change. Two stations previously separated by 5 degrees of rotation when the bandsread capacitor was used alone may now, with a padder inserted, be separated by 10 degrees of rotation.

S Meters. An *S* meter (signal-strength meter) measures the approximate or comparative strength of an incoming signal.

S-meters are found on the front panels of the more expensive communications receivers. An *S*-meter is a simple milliammeter with a scale calibrated in arbitrary *S* (signal strength) units. It is connected between the B+ bus and the plate load of the tube (Fig. 33-12a). Therefore, it does not read the incoming signal directly; it reads the effect of the signal upon the plate current of one or more i-f tubes in the receiver. Since plate current of a tube is controlled by AVC voltage on the control grid of the tube, and since AVC voltage is proportional to the strength of the incoming signal, plate current varies in accordance with signal strength. The *S* meter reads these plate current variations.

Since a strong signal increases negative AVC voltage that decreases the tube's plate current, the meter deflects less on strong signals than on weak ones. When no station is coming in, plate current is a maximum, and deflection is at maximum. A special meter, whose pointer rests at the right hand side of the scale when no current is flowing and at the left when maximum is flowing, is used.

The meter scale is calibrated from 1 to 9, with 9 located slightly to the left of midscale. Further to the right, the scale is calibrated in terms of decibels above S_9 (Fig. 33-12b). S_9 means a signal strength of 9. Signals above this

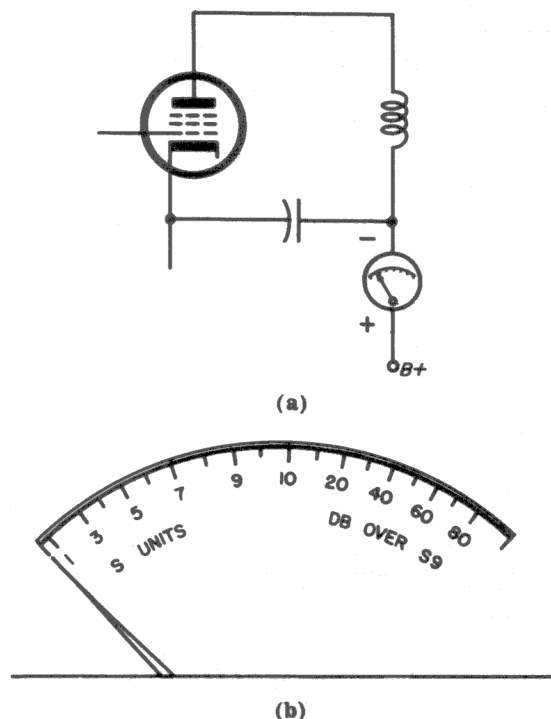


Fig. 33-12

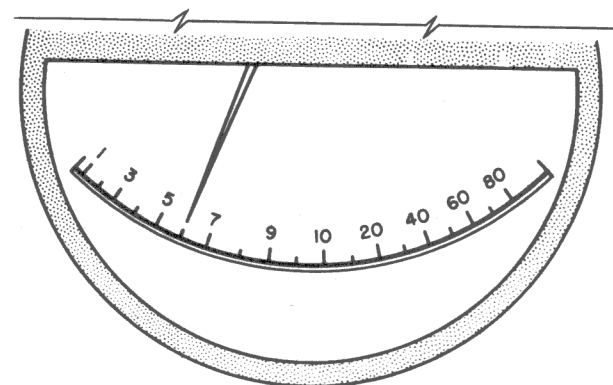
strength are measured in decibels with respect to S_9 . A strong signal would deflect the pointer as far as S_9 . A still stronger signal would deflect it perhaps to 10 db above S_9 , and so on.

The meter does not read signal strength with high accuracy because its deflection is influenced by factors other than signal strength alone. Aging tubes, misalignment of resonant circuits, variations of line voltage, and other factors modify its readings. But it does give good indications of *relative* signal strengths. It enables the operator to tell that station A is much stronger than another station B, not quite so strong as a third station C, etc. As a signal fades up or down and AVC action compensates, the *S*-meter needle swings and indicates the range of variation. In two-way communication, where each operator has both a transmitter and receiver, the meter enables each operator to report to the other the strength and steadiness of his signal. It also enables one operator to monitor the other's beam while the other varies the direction of propagation by turning his rotary antenna until optimum signal is received.

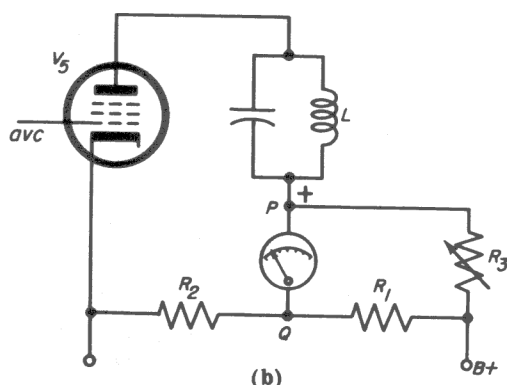
A 0-to-1-milliamper milliammeter may be used as an *S*-meter if it is inverted and

fitted with a scale lettered accordingly, as shown in Fig. 33-13a. Inverting reverses the direction of needle deflection. Or it can be left upright and a bridge circuit used to reverse direction of deflection; but then a more sensitive meter is required, because the bridge wastes some of the deflecting current.

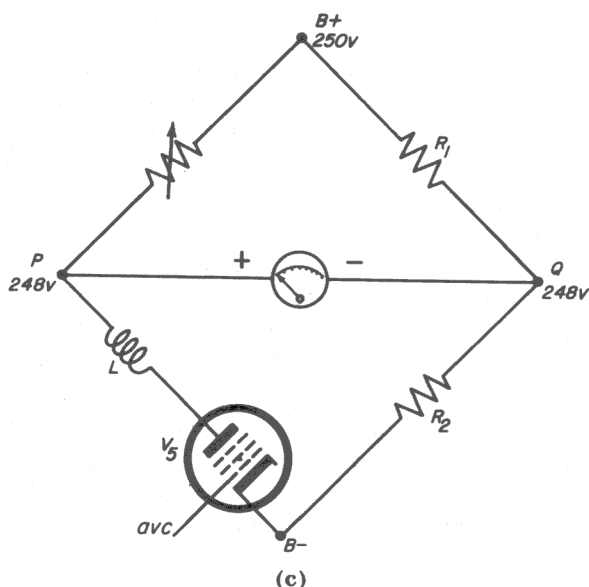
In the bridge circuit shown in Fig. 33-13b, the electron stream of the tube acts as



(a)



(b)



(c)

Fig. 33-13

a variable resistor controlled by AVC voltage. When AVC voltage is large, the tube conducts less current and is equivalent to a high resistance. When AVC voltage is small, the tube conducts more and is equivalent to a lower resistance. The electron stream and external resistor R_3 constitute a voltage divider. R_1 and R_2 also constitute a voltage divider. The two voltage dividers form the branches of a bridge circuit, with the meter indicating difference of voltage between two points P and Q, one on each divider. The circuit is redrawn at c to emphasize the bridge arrangement. The resistor R_3 is adjusted when no signal is coming in, and no AVC voltage is developed, so that point P on R_3V_5 voltage divider is at the same potential as point Q on the R_1R_2 voltage divider. With P and Q at the same potential, no current flows through the meter and no deflection results.

When a signal is tuned in, AVC voltage changes the equivalent resistance of V_5 , making the resistance higher. As the resistance of the tube rises, the potential at point P becomes more positive with respect to B-. P is now more positive than Q. Current flows from Q to P and the needle deflects from left to right. The stronger the incoming signal the further the needle deflects. Thus, a conventional meter is made to deflect in a manner that suits the normal-type meter. The pointer moves to the right to indicate increasing signal strength.

Standby-Receive Switch. When a transmitter and a receiver are operated in the same room, the receiver must be silenced while the transmitter is on the air. This prevents the receiver from reproducing the powerful signals from the nearby transmitter. If a signal were reproduced by the speaker of the receiver, the microphone would pick up the sound, feed it to the transmitter, which would retransmit it. The receiver would re-reproduce it, and so on. A feedback howl would be transmitted and would be continuous until either transmitter or receiver were shut off.

The standby-receive switch, Figure 33-14, renders the receiver inoperative in one position, by breaking the B+ supply to the r-f and i-f amplifier stages. This is much better

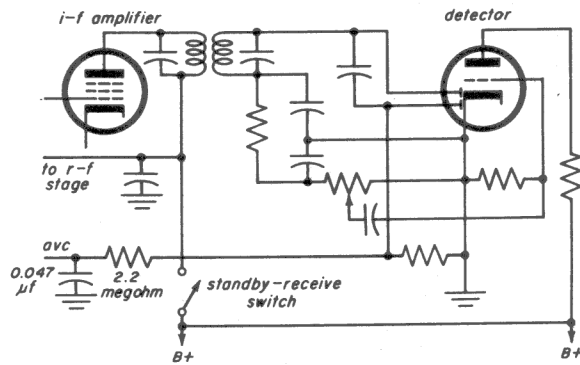


Fig. 33-14

than switching off all power to the receiver, because it allows the receiver to become operative instantly when the switch is thrown to the other position. If power is entirely cut off, the receiver cannot function instantly when turned on again, because time is required to heat the cathodes. In two-way communication, instant on-off and off-on control of the receiver is needed to save time. Also turning power off and on causes temperature changes and oscillator drift and detuning.

When the receiver is required to be on, the transmitter must go off or any accidental sound may start the continuous howl. Therefore, many receivers are equipped with a standby-receive switch so wired that when it turns the receiver on, it simultaneously switches the transmitter off, and vice versa. An outlet at the rear of the receiver allows a suitable on-off switch in the transmitter to be appropriately interconnected with the receiver's standby-receive switch.

33-4. A POPULAR 3-WAY MULTIBAND RECEIVER

Figure 33-15 shows a schematic diagram of a sensitive, versatile and portable multiband receiver. It may be operated on a-c, d-c, or battery power. When equipped with a suitable adapter, it may even be operated from the 234-volt power systems of many foreign cities.

It is a receiver intended for pleasure. It is not a communications receiver. It does not have such characteristic communications accessory circuits such as BFO, ANL, crystal filter, and standby-receive switch. It omits the short-wave bands intended primarily for

code, facsimile, radiophoto, etc. But it includes the intercontinental news and entertainment bands, as well as two bands, called by the manufacturer *B* and *C* bands, just above the broadcast band. The *B* band extends from 2 to 4 mc, the *C* band from 4 to 6 mc.

This receiver does not have critical tuning. It uses the moderately high tuning ratio of 11-1/2 : 1. Instead of dividing the short-wave frequencies covered into two or three bands, it divides them into six bands. Thus, no one band has a wide range of frequencies to be covered. No band is crowded. It uses a six-section variable capacitor. Three of the sections have a capacitance range appropriate for the broadcast band. They tune the antenna-input circuit, the r-f stage, and the oscillator tank. These three sections, in series with suitable fixed bandspread capacitors, also tune the *B* and *C* bands, when the bandswitch is in the *B* or *C* position. The three remaining sections, having small plates and small capacitance ranges (7 μf to 12 μf), serve as bandspread capacitors for the remaining four short-wave bands. The bandspread rotors are on the same shaft as the main rotors. But when the bandswitch connects the bandspread sections to the appropriate shortwave coils, it simultaneously disconnects the stators of the main sections. Thus, although the main rotors turn with the bandspread rotors, the main rotors have no effect upon the frequency of the resonant circuits. Only the small bandspread sections affect the resonant frequency. (This arrangement differs from the one we discussed, in which the bandspread capacitors were on a separate shaft but were connected in parallel with the main sections. Here, when the bandspreader capacitors are in the circuit, the main sections are out.) The bands covered by this receiver are:

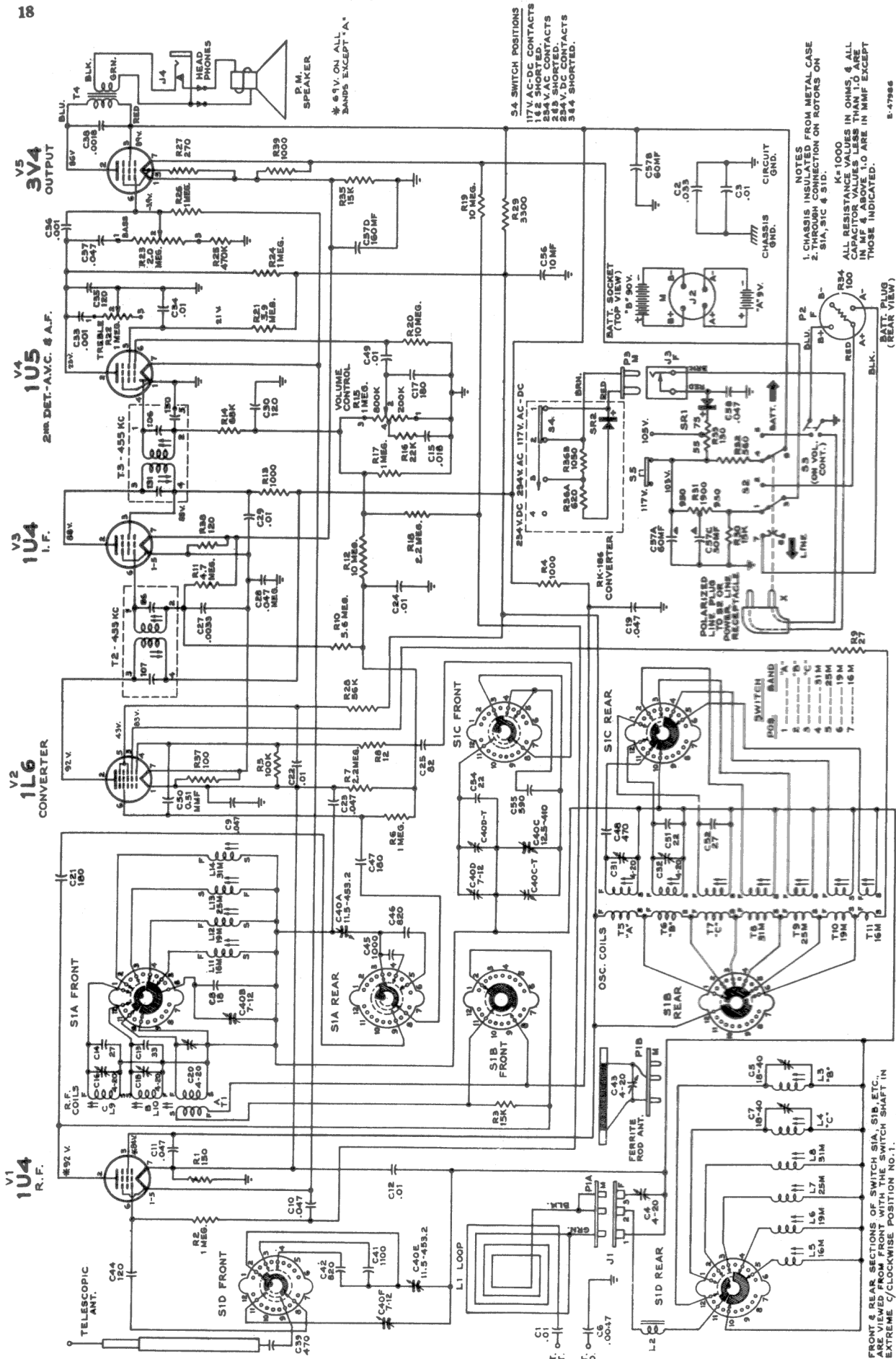
Broadcast band.

B band (2 to 4 mc)

C band (4 to 8 mc)

31-meter band (9.45 to 9.85 mc)

25-meter band (11.55 to 12.05 mc)



Schematic Diagram - RCA Victor Chassis No. RC-1125

19-meter band (14.90 to 15.55 mc)

16-meter band (17.50 to 18.20 mc)

As the bandswitch is turned to the desired band, it connects either the main or the bandspread sections of the variable capacitors to coils, in the antenna, r-f, and oscillator circuits. These coils have just enough inductance to cover the desired band with the capacitance range of the sections now connected to them.

Three antennas are provided. For the broadcast band, the antenna is either a flat loop in the hinged lid of the case or a ferrite-rod antenna, equipped with a suction cup to stick on a window when aboard a train or plane. A flexible twin lead connects the rod antenna to the receiver. For shortwave reception, a telescoping tubular antenna is drawn up out of its compartment in the case. It is coupled by C_{39} directly to the hot end of the input resonant circuit. No primary is used. This arrangement allows maximum transfer of signal from the short antenna.

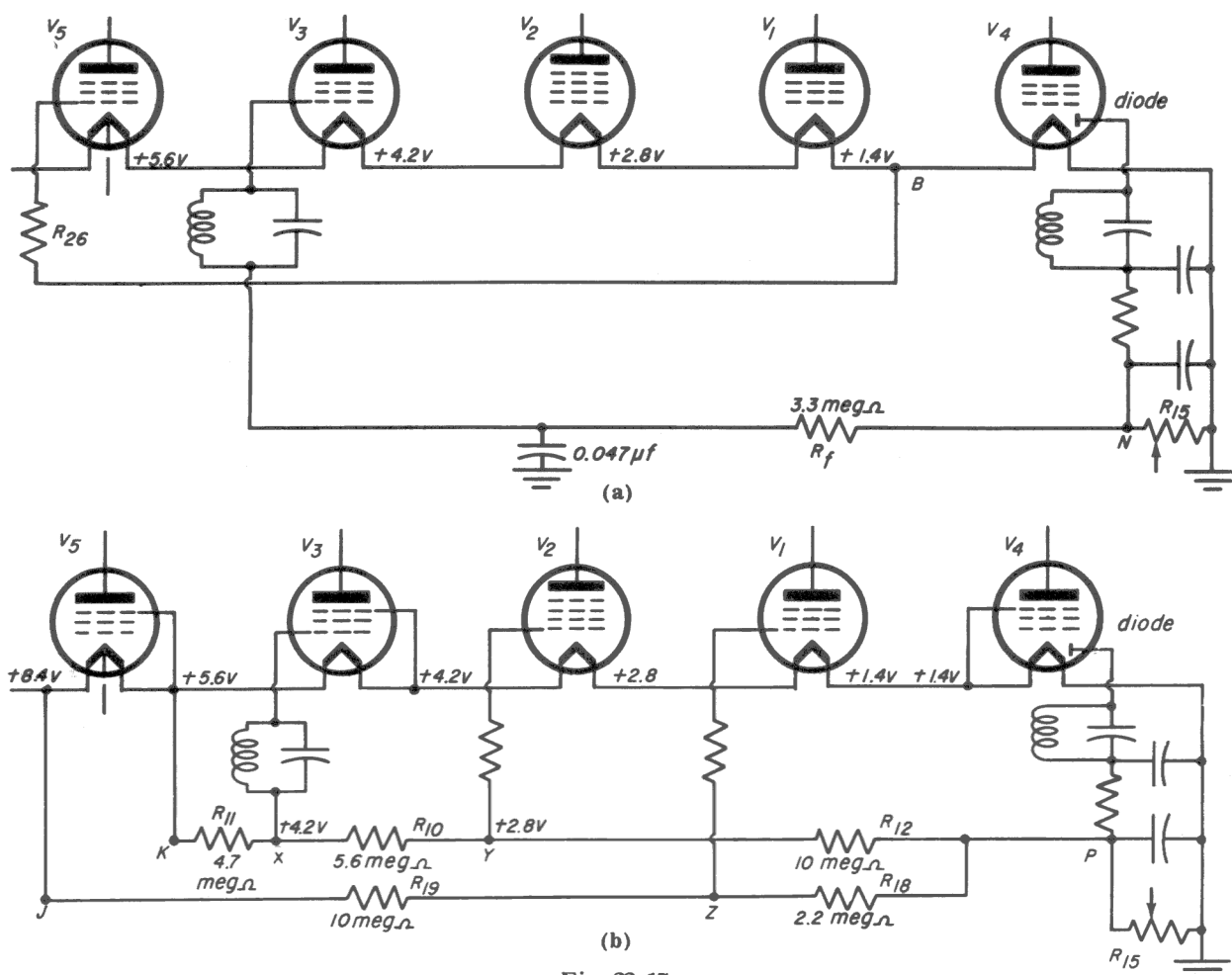
The circuit changes made by bandswitches are always somewhat difficult to follow when reading the schematic diagram of a multiband receiver. However, much of this difficulty can be removed with a few colored pencils. If the B^+ bus is traced out in red on the schematic, it serves as a guide to the eye and helps to visually relate to each other all the components through which B^+ current flows. The colored line should follow the B^+ route through resistors and coils right to the plates of the tubes. Similarly, a line of different color, such as green, traced over the AVC voltage bus, and still another line—blue, for instance—traced over the zero-signal, or circuit-ground bus, help greatly to clarify interrelations. (The zero-signal bus for r-f resonant circuits may be isolated from the d-c ground by one or more capacitors. It can usually be identified as the wire to which most of the coils have one end connected. In Fig. 33-15 it is the line connecting the lower end of L_5 to the zero-signal end of many other coils.)

The metal contactor strips on the rotor part of a wafer switch (for instance, S_{1A})

may be connected to a strip on the reverse side of the rotor disk. This is difficult to show clearly in schematic diagrams. In the schematic diagram of Fig. 33-15, it is shown by a small dark semicircular hole in the rotor disc through which a short tab on the metal strip passes, to make contact with the strip on the other side. One of the strips on the front of S_{1A} is shown by this method to be connected to the strip on the rear of S_{1A} . Similar connections are shown on S_{1C} and S_{1D} . Unless these connections are recognized, the schematic diagram does not make sense. Note that in the lower left corner of the figure you are told that the switch is shown in position 1. At the center of the diagram, a table tells that position 1 activates band A (the broadcast band). Always look for such information before trying to understand a multiband schematic.

A careful study of the switching connections will show you that as the switch inserts some coils into the resonant circuit, it shorts the ends of other coils. This is done because a coil for one short-wave band, even though disconnected from the variable capacitor, may have enough distributed capacitance in its windings and associated wiring to be self-resonant at a frequency in a higher band. Resonant circuits absorb energy from an exciting source, so that self-resonant coils might absorb energy from a desired signal developed across another coil, thereby weakening the signal. Consequently, coils likely to have this effect are shorted out when not in use by the switch.

The method of transferring signal from V_1 to V_2 is interesting. For the broadcast band, a conventional r-f transformer, T_1 , is used (Fig. 33-16a). It consists of an untuned primary and tuned secondary. Transfer of energy occurs by magnetic coupling and is quite satisfactory. But the method would be much less satisfactory for the short-wave bands. At the much higher frequencies of the short waves, the tiny amount of internal capacitance between plate and grid of V_1 —largely but not wholly eliminated by the screen grid—plus the external capacitance due to wiring, have a low enough reactance to provide an effective feedback path from



of the resistors are so chosen that point Z is at +1.75 volts or slightly more positive than the low end of V_1 . When a very weak station is coming in, the noise voltages develop a small amount of AVC bias—just about enough to lower point Z to +1.4 volts, providing zero bias for V_1 and maximum gain from it. Because of the position on the voltage divider of supply point Z (close to AVC source P), V_1 is the tube most sensitive to AVC voltage. It produces the largest change in over-all receiver gain for a given change in AVC bias.

The second voltage divider, K , consists of very high ohmage resistors R_{11} , R_{10} , and R_{12} plus R_{15} . It is connected between ground and the +5.6 volt point on the filament string. The resistor values are so chosen that point X is at the same potential above ground as the low end of the filament of V_3 , and point Y is at the same potential above ground as the low end of the filament of V_2 . Thus when

no AVC is being developed, the voltage dividers hold the two grids at zero bias, or at maximum gain.

High ohmage resistors are used in the dividers so that they will impose a very light load upon the AVC voltage source.

When AVC voltage is developed at point P , it alters the voltage drop across the voltage dividers, and therefore alters the potential at the supply points X , Y , and Z , in the negative direction. That is, the grids of the controlled tubes become negative with respect to the low ends of their filaments. The stronger the incoming station, the more the supply points change in the negative direction. Thus, the voltage dividers fulfill the requirements for AVC distribution. AVC voltage filter capacitors C_{10} , C_{24} , and C_{27} , have been omitted from b for the sake of simplicity.